TRANSPORT OF MAW/LAW GRANULE SUSPENSION THROUGH VERTICAL PIPES INTO CAVERNS

H. H. Homann, NUKEM GmbH
M. Weber, Y. Dedegil
Inst. F. Foedertechnik, Univeristaet Karlsruhe

INTRODUCTION

As an alternative to the processes successfully tested in the FRG in the past for ultimate storage of medium- and low-level radioactive wastes from the reprocessing of nuclear fuel, the containerless storage and solidification of these wastes in caverns is being studied. In this process, preconditioned MAW/LAW granules are mixed with a filler suspension consisting of tritium water and cement and then transported through a vertical pipe from ground level directly into the cavern, where the product solidifies to a quasi-monolithic block which has mechanical characteristics similar to those of the surrounding rock. These characteristics, in conjunction with the short time that the cavern is open and the complete filling of the cavern, result in a distinct increase in the stability of an ultimate storage facility while simultaneously reducing the specific cavern volume requirement. Additional advantages offered by this process are the avoidance of underground transportation of the waste as well as the reduction in the radiological exposure of personnel and the environment.

STUDIES OF THE TRANSPORT OF GRANULE SUSPENSION THROUGH VERTICAL PIPES

Studies which are conducted in conjunction with a feasibility study resulted, at an early stage, in the selection of a transport process which can be describes as follows.

A fluid, incompressible mixture consisting of granules, cement and mixing water containing H3 flows automatically through a vertical pipe, filling the pipe completely at the point where the mixture passes through it, into the cavern. The process is inherently safe and operates under atmospheric pressure. The fact that mechanical conveyor mechanisms, for example pumps, are not required, results in reducing maintenance and repair work, while simultaneously increasing the system availability.

In order to minimize abrasion of the transport pipe and of the product itself, the average speed of the product in the vertical pipe in this process is selected much lower than the corresponding rate of free fall. This lower speed is achieved by dimensioning the diameter of the vertical pipe, as a function of the quantity of product transported and the rheological characteristics of the product, in such a way that the opposing forces of wall friction and gravity in the pipe counterbalance each other.

In order to determine the rheological data required for design of such a system an experimental program was carried out with the following objectives:

- Optimizing the product compostition with respect to a maximum granule loading with adequate transportability.
- Determining the pipe characteristics as a function of the nominal diameter.
- Determining the spreading behavior as a function of the development of the angle of repose and separation of the mixture into its components as a result of radial spreading.

The results of these studies can be described as follows:

- Optimizing the product composition

A parameter of crucial importance for the degree of utilization of the cavern is the proportion of granules, the actual source of activity, in the granule-filler suspension. Earlier studies of the temperature development showed the necessity for an aboveground preconditioning of the MAW/LAW waste concentrates because otherwise, if pure cement suspensions are fed into the cavern, the temperature within the product rises to values higher than 150°C due to the release of hydration heat. Since improved filling of the cavern results with polydispersed granules in comparison with monodispersed, a material with a polydispersed grain spectrum, as shown in Fig. 1 was used for the studies. A blast-furnace cement, Type HOZ 35 L NW/HS was used for production fo the filler suspension. As additives, a liquifier and a retarder, both produced by Halliburton, were used.

Adequate transportability was attained using a product containing the materials mentioned above and with the composition listed in Table I; this product was specified as the reference mixture for all further experiments.

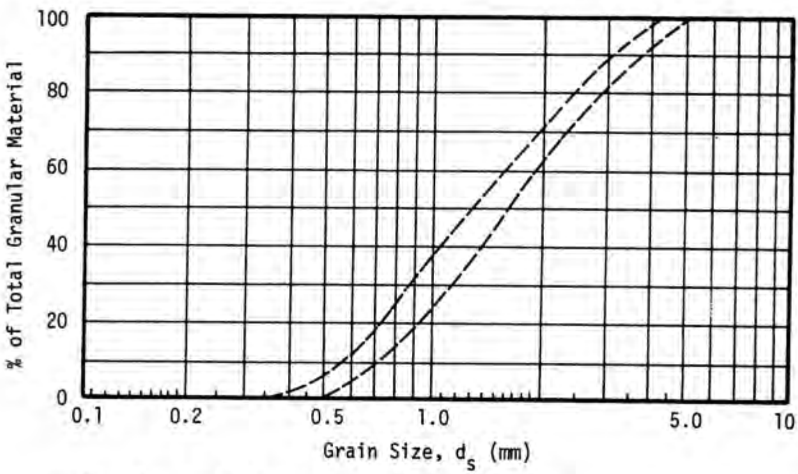

Fig. 1. Grain Spectrum of the Granules Used.

Table I: Composition of the reference mixture at T = 17°C

Material	Mass %	Vol. %	Wtr.-cem. ratio	Theor. density /g/cm³
Granules	71.6	66.2		
Cement	19.2	13.6	0.45	2.20
Water	8.6	19.0		
Retarder	0.3	0.6		
Liquifier	0.3	0.6		
Total	100.0	100.0		

- Determining the pipe characteristics as a function of the nominal diameter

Using the reference mixture specified above, the pipe characteristics for various pipe diameters were determined on a test stand. The results for the diameters 52, 64 and 82 mm are compiled in Table II.

Table II: Transport pipe characteristics as a function of the vertical pipe diameter.

Pipe diameter	Δt	Δm	Δv	δ	$\dot{m}$	$\dot{V}$	v	$\dot{V}$
mm	s	kg	l	g/cm³	kg/s	l/s	m/s	m³/h
52	19.6	16.98	10.02	1.676	0.870	0.513	0.24	1.85
64	8.9	18.47	10.59	1.745	2.105	1.206	0.375	4.34
82	4.7	18.12	10.38	1.745	3.86	2.21	0.42	7.86

When carrying out these experiments, using a system with a transport length of about 8.5 m, it was found that for start-up operation a "lubricant mixture" composed of a cement suspension without granules and with a water-cement ratio of at least 0.45 must first be passed through the system, because otherwise the tip of the mixture stream loses water as a result of wetting the inside wall of the pipe and thus the pipe becomes clogged.

- Determining the spreading behavior, angle of repose and separation of the mixture into its components

An essential parameter for the degree of filling of a cavern is the angle of repose that develops during the filling operation. In addition, knowledge of the degree of separation of the product into its components as a result of radial spreading in the cavern is essential to ensure the quality of the stored product following solidification.

As early as in the transport experiments mentioned above, the reference mixture considered showed good spreading characteristics with a free-flow cone of 3 - 4°. Even in experiments with free-fall heights up to 20 m, there was no change in the angle of repose behavior. The study of the concentration distribution of the granules as a function of the distance from the center of the "cake" revealed no significant deviations from the original values, so separation processed, due to radial spreading, can be regarded as negligible, if they are present at all.

In order to evaluate questions that are still open such as, for example, testing of special components, determination of operation needs and requirements, testing of a suitable mixing and dosing subsystem, etc., and experimental system with a transport length of 50 m and a mixing and transport capacity of about 2 m^3/h is currently being constructed and operated in conjunction with a supplementary testing program at the experimental ultimate storage facility ASSE II. It is assumed that, when these experiments have been concluded, the data required for the construction and operation of a prototype system will be available.

CONCEPT OF A SYSTEM FOR TRANSPROT OF MAW/LAW GRANULE SUSPENSIONS THROUGH VERTICAL PIPES

The basic specification for the development of a system concept was an annual disposal capacity of 15,000 m^3 of product. Due to the close process engineering connection between production and transport of the product, the concept presented includes the equipment for production of the granule-filler suspension in addition to the actual transport system.

- Production of the granule-filler suspension

The system for production of the granule-filler suspension is shown schematically in Fig. 2.

The individual components of the mixture, granules, cement and tritium concentrates, are fed separately from their buffer storage tanks into the dosing and mixing equipment. Dosing of the individual components, corresponding to the reference mixture specified, takes place by means of a gravimetric feeder which supplies the continuously operating mixer. Production-induced fluctuations in the consistency of the granule-filler suspension and the resulting changes in the flow behavior are detected and balanced out by two subsystems which operate independently of each other. With these two subsystems an increase in the viscosity, with constant mixing output, results in a decrease in the transport capacity and raises the level of the mixture in the feed hopper B01 in the transport system. By means of a continuous level indication operating from pressure gauges the mixing output is automatically regulated if a maximum value is exceeded. In parallel with this operation the consistency of the product is monitored through the power consumed by the drive mechanism for the scraper in the same hopper. Here, an increase in the viscosity results in an increase in the power consumed by the drive. By controlled addition of water or additives the mixture is again adjusted to the required viscosity.

- Transport of the product

Figure 3 shows the schematic construction of the transport system.

The product, consisting of granules and filler suspension corresponding to the specified formulation, is fed continuously from the upstream mixing process to the feed hopper B01 in the transport system.

In order to avoid wall incrustations, the hopper is equipped with a scraper R01. By means of a spray mechanism the hopper can be cleaned when the system has been taken out of operation. The hopper is mounted in a movable bridge and is coupled to the transport line through the shut-off fitting V001 and the coupling X101. The transport line is fastened in a suspended position to hanger X102. In event an intervention operation is necessary, the feed hopper is moved into its intervention position and then the line can be withdrawn with a crane and disassembled, see Figs. 4 and 5.

The individual operating conditions of the system can be described as follows:

- Start-up operation

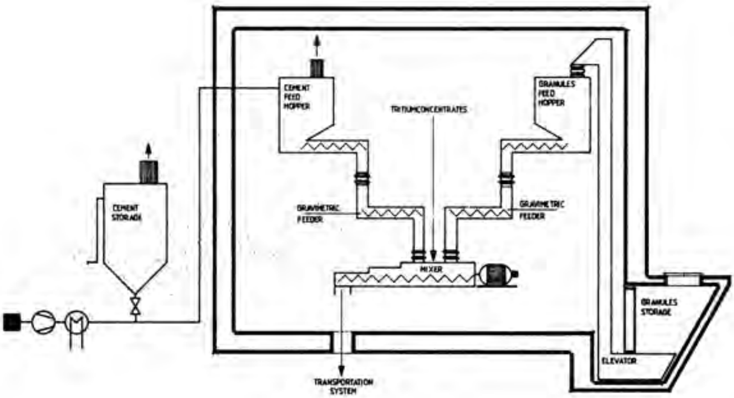

Fig. 2: Principle flow diagram of the granule suspension production process

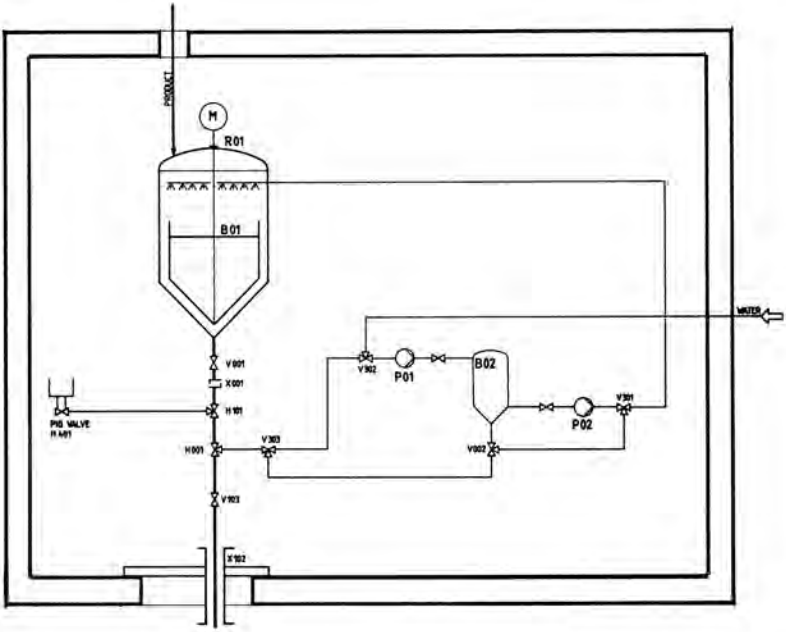

Fig. 3: Principle flow diagram of the transportation process

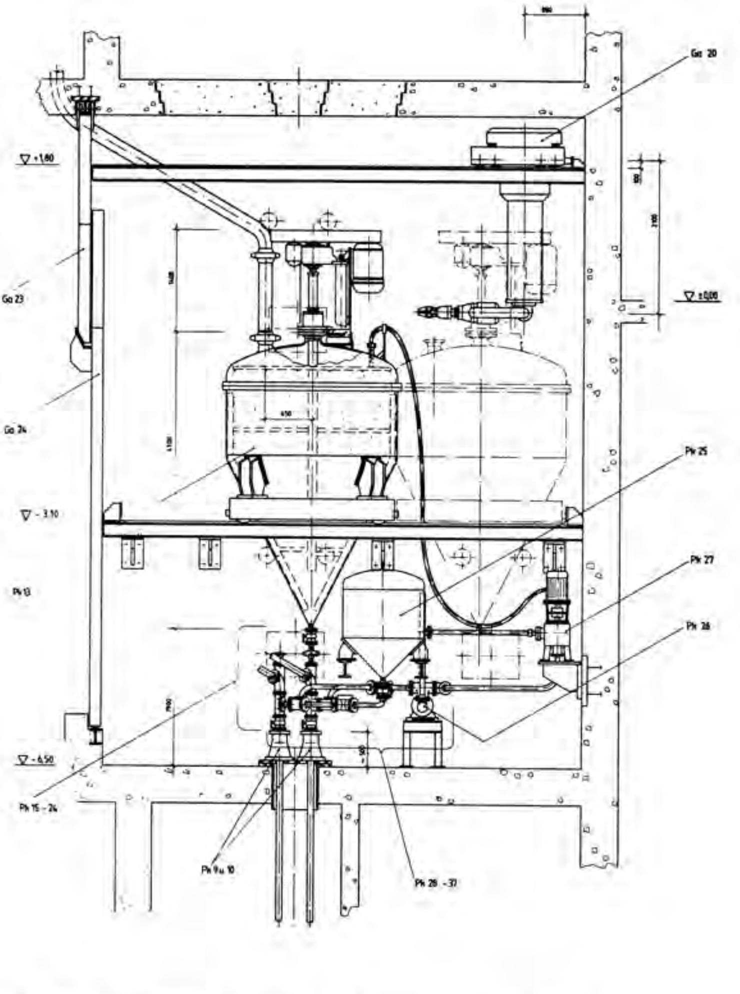

Fig. 4: Conceptual design of the transportation process

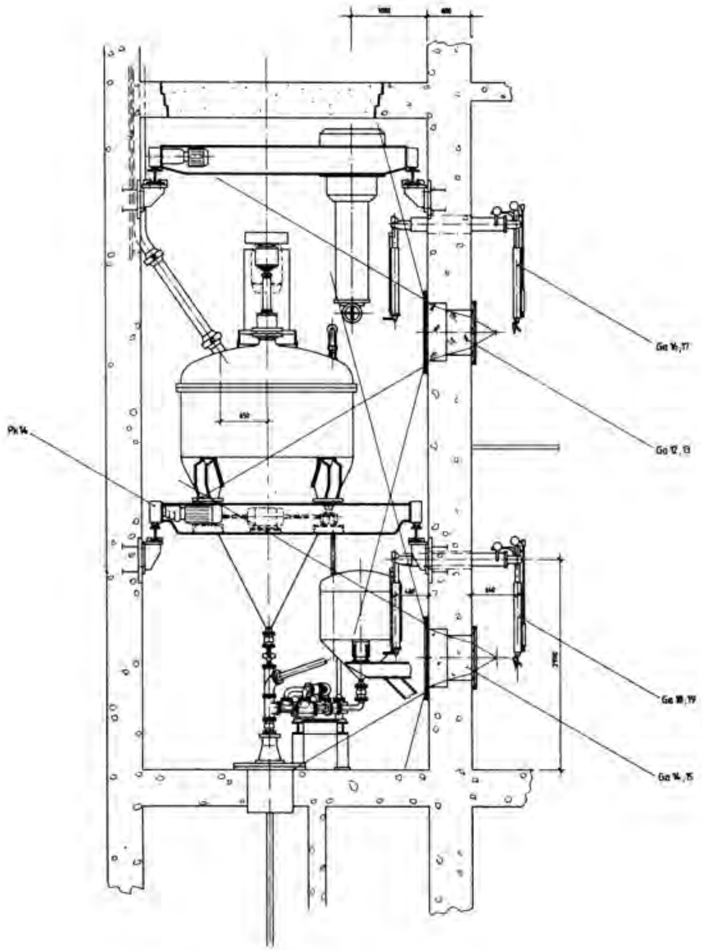

Fig. 5: Conceptual design of the transportation process (cross section)

In order to wet the surfaces of the pipe and set the process engineering parameters, the transport system is started up with a cement suspension with a water-cement ratio = 0.45 without granules. The production of about 2 - 3 m^3 of cement suspension is carried out with the continuously operating mixer in the system. When the operating condition has been reached the granules are dosed into the suspension and thus the product with the rated specifications is fed into the line and transported through it.

During operation the transport line is cleaned at regular intervals of time with pigs to avoid incrustation. The pigs are remote-controlled with the manipulator placed in the pig lock H401 and introduced hydraulically into the transport system.

- Shut-down operation

Following conclusion of a storage operation, the transport system is emptied, cleaned and preservative steps are taken. After the feed hopper has been emptied a cleaning pig is introduced into the system through the pig valve H401 and the transport line is cleaned. The transport medium for the pig is the spent rinsing solution in the cleaning circuit.

The feed hopper B01 is equipped with an internal, high-pressure rinsing system. For rinsing purposes the fitting V001 at the hopper is closed and the rinsing solution is collected in the hopper B01 and, after fittings V001, H001, V303 and V302 have been opened, this solution is pumped back into the rinsing circuit tank B02 by pump P01. The tank B02 is designed in such a way that the solid components settle in the pump and the clear solution is available for a renewed rinsing operation.

After the cleaning work has been completed, the rinsing solution is released through fittings V002, V303, and H002 into the transport line, through which it flows into the cavern.

As a system-typical operating malfunction the clogging of one transport line was assumed for the system. In order to sustain the storage operation in this case as well, the transport line was designed in a redundant form with the concept considered. Restarting of the system in event <u>one</u> transport line becomes clogged is carried out as follows:

If the transport line that is in operation becomes clogged the level of the mixture in the feed hopper rises. When a limiting value is exceeded the upstream mixing subsystem is switched off and influx of the product is thereby interrupted. Fitting V001 on the feed hopper is closed and the hopper is disconnected from the clogged transport line at the coupling X101 positioned over the redundant transport line by means of the movable bridge and is connected to the latter line.

In order to restart the system with the new line a cement suspension with a water-cement ratio of 0.45 is produced, similar to the procedure with initial operation, and after introduction of a pig, this suspension is fed into the transport line through V302, V303 and H001. After feeding about 2 - 2 m^3 of cement suspension into the transport pipe the fitting H001 is opened to the main passage direction by opening the hopper shut-off fitting V001 and transport of the product is continued. When transport of the product has resumed, the upstream mixing process is also set in operation again and the system reverts back to normal operation.

As the last measure the fittings V302 and V303, with the associated piping, are cleaned by switching fitting V301 over to the rinsing circuit.

Following conclusion of the storage operation the clogged transport pipe is removed and replaced by a new pipe.

The concept of the transport system for containerless ultimate storage of medium- and low-level radioactive wastes considers the remote-controlled operation of the system including all maintenance and intervention work. Intervention operations such as, for example, the withdrawal and replacement of clogged transport lines can be carried out with equipment included in the system.